

## Claims

- [c1] A micro-electromechanical system (MEMS) switch comprising:
  - a movable beam within a cavity, said movable beam being anchored to a wall of said cavity;
  - a first electrode embedded in said movable beam; and
  - a second electrode embedded in an wall of said cavity, facing said first electrode, wherein said first and second electrodes are respectively capped by a metallic contact.
- [c2] The MEMS switch as recited in claim 1, wherein said metallic contact of said first and second electrodes respectively protrude above said first electrode and below said second electrode.
- [c3] The MEMS switch as recited in claim 1, wherein said first electrode is a signal electrode and said second electrode is an actuation electrode.
- [c4] The MEMS switch as recited in claim 3, wherein said actuation and signal electrodes are made of copper.
- [c5] The MEMS switch as recited in claim 1, wherein said movable beam is anchored to the wall of said cavity at at least one end thereof.

- [c6] The MEMS switch as recited in claim 1 where said metallic contact is selected from the group consisting of Au, AuNi, AuCo, Pt, PtNi, Ru, Ru, Rh, Os, Ir, Pd, PdNi, and PdCo.
- [c7] The MEMS switch as recited in claim 1, wherein said cavity is filled with gas, said gas being selected from the group consisting of nitrogen, helium, neon, krypton and argon.
- [c8] The MEMS switch as recited in claim 1, wherein the metallic contact of said second electrode has a flat surface that is smaller than the surface of the metallic contact of said first electrode.
- [c9] The MEMS switch as recited in claim 1, wherein said dielectric is made of SiN,  $\text{SiO}_2$ , SiON, SiCH, SiCOH, SiCHN,  $\text{TiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HFO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Ta}_2\text{O}_3$  and combinations thereof.
- [c10] A micro-electromechanical system (MEMS) switch comprising:
  - a movable beam within a cavity anchored to a wall of the cavity;
  - at least one conductive actuation electrode embedded in a dielectric;
  - a conductive signal electrode embedded in dielectric in-

tegral to said movable beam;  
a raised metallic contact capping said conductive signal electrode and a recessed metallic contact capping said actuation electrode.

- [c11] The MEMS switch as recited in claim 1, wherein said caps of conductive signal electrodes are made of noble material, and said actuation and signal electrodes are made of copper.
- [c12] The MEMS switch as recited in claim 1 wherein said recessed metallic contact is made of a material selected from the group consisting of Au, AuNi, AuCo, Pt, PtNi, Ru, Rh, Os, Ir, Pd, PdNi, and PdCo.
- [c13] The MEMS switch as recited in claim 1, wherein the exposed surface of said second electrode is recessed below the exposed surface of said dielectric, and said cap superimposed on top of said second electrode matches the exposed surface of said dielectric.
- [c14] A method of forming a raised lower noble metal contact disposed on a substrate, comprising the steps of:
  - a) embedding metal electrodes on said substrate;
  - b) capping said metal electrodes with a first dielectric layer;
  - c) depositing a second dielectric layer on said first di-

electric layer;

- d) selectively reactive ion etching said first and said second dielectric layers to form a contact pattern therein, exposing said metal electrodes;
- e) depositing a refractory metal layer on top of said second dielectric layer; and
- f) depositing a blanket noble metal, said noble metal being shaped by a chemical-mechanical planarization process (CMP), stopping at said refractory metal;
- g) selectively removing said refractory metal in field areas, and stopping at said second dielectric layer; and
- h) removing said second dielectric layer by reactive ion etching stopping on said first dielectric layer, yielding said raised noble metal lower electrode.

- [c15] The method as recited in claim 14, wherein said substrate is made of a material selected from the group consisting of Si, GaAs, and glass.
- [c16] The method as recited in claim 14, wherein said substrate is provided with at least one wiring interconnect level and integrated analog and logic circuitry.
- [c17] The method as recited in claim 14, wherein said first dielectric is selected from the group consisting of SiN, SiO<sub>2</sub>, SiON, SiCH, SiCOH, SiCHN, TiO<sub>2</sub>, ZrO<sub>2</sub>, HFO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub>, Ta<sub>2</sub>O<sub>3</sub> and combinations thereof.

- [c18] The method as recited in claim 14, wherein said second dielectric is selected from the group consisting of DLC, SiLK, Polyimide, SiN,  $\text{SiO}_2$ , SiON, SiCH, SiCOH, SiCHN, and combinations thereof.
- [c19] The method recited in claim 14, wherein said second metal is deposited in-situ to prevent a formation of oxide between said first and second metals.
- [c20] The method as recited in claim 14, wherein said first metal is selected from the group consisting of Ta, Ti, W, Cr, Zr, Hf TiSi, TaSi, TaN, TiN, Hf, Ru, Rh, Re and alloys thereof, and wherein said second metal is selected from the group of noble metals consisting of Ru, Rh, Re, Ir, Pt, Au, and alloys thereof.
- [c21] The method as recited in claim 14, wherein said noble metal contact is provided with a flat and smooth surface, said flat and smooth surface being formed by a hard-mask stack over an organic release layer and etched to avoid microtrenching to produce a flat and smooth contact recessed within a gap area.
- [c22] The method as recited in claim 14, wherein said noble metal contact is provided with fangs local to the contact openings to achieve an improved contact force, said contact being formed by microtrenching features that

are transferred into an organic gap layer to produce an area contact recessed within the gap area.

[c23] The method as recited in claim 14, further comprising forming an upper contact electrode facing said raised lower noble metal contact, the method comprises the steps of:

- a) depositing on said first dielectric layer a patterned sacrificial layer followed by a second dielectric layer thereon;
- b) planarizing said second dielectric layer by chemical mechanical polishing;
- c) depositing on said planarized layer a third dielectric layer followed by a fourth dielectric layer;
- d) forming a lithographic stencil pattern on said fourth dielectric layer and selectively etching by reactive ion etching (RIE) said fourth dielectric layer, stopping at said third dielectric layer;
- e) RIE etching said lithographic stencil, selectively removing portions of said third dielectric layer, said etching allowing microtrenching to occur locally on etched features to form said upper contact electrode;
- f) exposing to another selective RIE etch to recess said upper contact electrode into the sacrificial material area;
- g) metallizing said upper contact electrode; and
- h) chemical mechanical polishing (CMP) to remove said

metal from non-patterned areas of said third and fourth dielectric layers.

- [c24] The method as recited in claim 23, wherein said CMP process in step i) stops at said third dielectric when planarizing said fourth dielectric layer, and wherein the top surface of said metal is significantly planar with respect to said third dielectric layer.
- [c25] The method as recited in claim 23, wherein said sacrificial material is selected from the group consisting of DLC, SiLK, polyimide, carbon, a carbon based compound mixed with hydrogen nitrogen or oxygen, and wherein said dielectric layers are formed from a material selected from the group consisting of SiN,  $\text{SiO}_2$ , SiON, SiCH, SiCOH, SiCHN,  $\text{TiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{HF}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Ta}_2\text{O}_5$  and a combination thereof.
- [c26] The method as recited in claim 23, wherein said second dielectric layer is made of material selected from the group consisting of SiN,  $\text{SiO}_2$ , SiON, SiCH, SiCOH, SiCHN,  $\text{TiO}_2$ ,  $\text{ZrO}_2$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{Ta}_2\text{O}_5$ , DLC, SiLK, polyimide, and combinations thereof.
- [c27] The method as recited in claim 23 wherein said metal is selected from the group consisting of Ru, Rh, Re, Ir, Pt, Au, W, Ta, Ti, Cr, Zr, Hf, TiSi, TaSi, TaN, TiN, Hf and

combinations thereof.